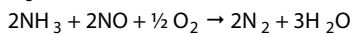


# Long-kiln SNCRs

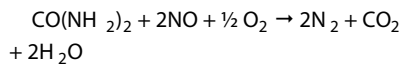
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Selective Non-Catalytic Reduction (SNCR) is a commonly-used air pollution control method in the cement industry to remove nitrogen oxides (NO<sub>x</sub>). SNCRs have been applied most often to preheater-precalciner (PH-PC) lines. However, recently an innovative approach has been successfully applied by installing and operating the SNCR to long wet and long dry kilns to remove raw material and kiln-firing NO<sub>x</sub>.

The key governing NO<sub>x</sub> removal chemistry is where the NO in the kiln reacts with aqueous ammonia (NH<sub>3</sub>) as follows:

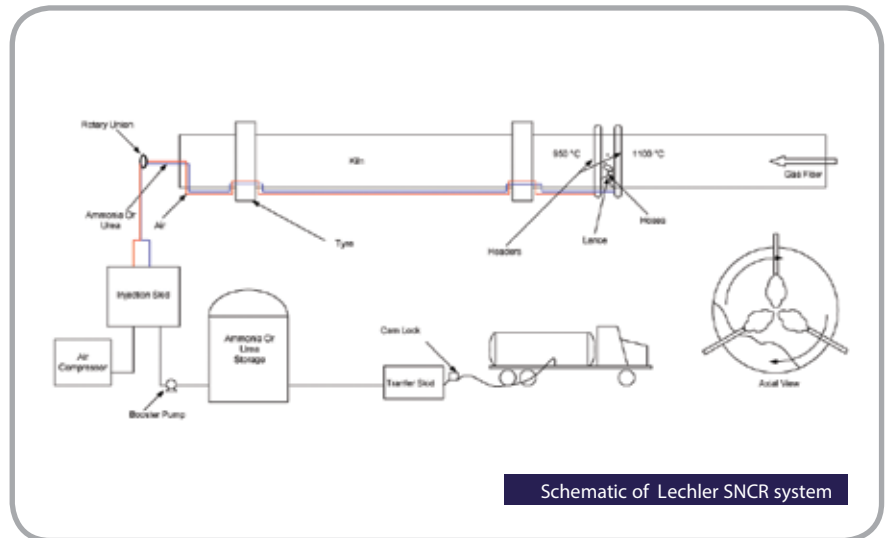


If urea is used, the reaction is:



Either reaction leads to the formation of nitrogen as shown in Figure 1.<sup>2</sup> The ammonia and urea is spray-injected in an aqueous water solution. With either reagent, if the temperature is too low, un-reacted reagent will 'slip'. If the temperature is too high, some or all of the nitrogen present in the reagent may be oxidised to NO. The optimum temperature range to spray into for aqueous ammonia is about 870-1150°C (1600-2100°F).

For the reduction reaction to occur, the reagent must be dispersed and mixed throughout the flue gas so that there can be sufficient contact between the NO<sub>x</sub> and the reagent. Dispersion must occur rapidly due to the volatility of the ammonia solution. It has been thought that mixing is performed by the injection spray lances. The spray nozzle lances atomise the reagent and control the spray angle, velocity and direction of the injected reagent. To assist in dispersion the aqueous ammonia is atomised into spray



Schematic of Lechler SNCR system

droplets by selected spray nozzles that optimise droplet size and distribution. The spray nozzle type, location and number of spray injection points affect the success of NO<sub>x</sub> reduction.

In early 1994, an SNCR vendor announced the first demonstration of urea-based SNCR on a US cement kiln/calciner process. The objective was to reduce NO emissions below 422pph. Test results indicated that reductions well below this level were achieved. At that time the Environmental Protection Agency's (EPA) draft Alternative Control Techniques (ACT)

document for cement manufacturing concluded that SNCR was not applicable to long wet and dry kilns due to difficulties involved in continuous injection of reducing agents. For preheater and precalciner kilns, however, potential SNCR NO<sub>x</sub> removal efficiencies were reported at 30-70 per cent.

US-based consultant John Kline, who examines

SCR and SNCR systems, said: "At present, selective non-catalytic reduction (SNCR) technology is considered the best available control technology for cement plants. In the SNCR process a reducing reagent is injected into the NO<sub>x</sub>-laden gas stream. Reagents are usually ammonia based with aqueous ammonia being the most common. Other reagents include urea and anhydrous ammonia. SNCR reactions occur most effectively in the 800-1000°C temperature range. Above 1000°C the ammonia compounds can decompose to form NO<sub>x</sub>. Below 800°C the reactions are incomplete, leading to increasing ammonia emissions (often called ammonia slip) as the temperature drops.

"Designing SNCR systems for modern preheater/precalciner kilns is fairly simple as the temperature profile in the preheater is easy to identify and control. The effectiveness of the system depends primarily on the dispersion of the reagents within the gas stream. Good dispersion allows for NO<sub>x</sub> reduction at close to the molar ratio between reagent and NO<sub>x</sub> as long as the NO<sub>x</sub> reduction is less than 50 per cent.

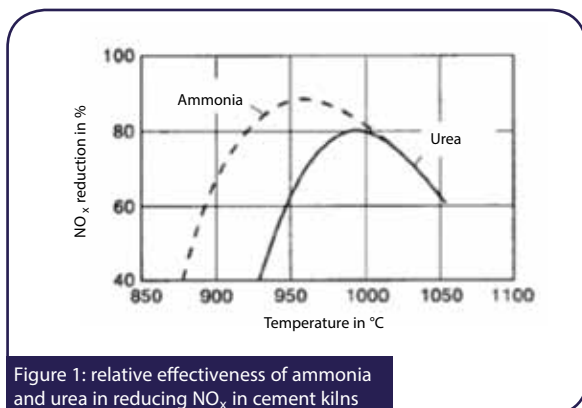


Figure 1: relative effectiveness of ammonia and urea in reducing NO<sub>x</sub> in cement kilns



Figure 2: injection location into the rotating kiln

“Designing SNCR systems for long wet and long dry kilns is more challenging. The proper temperature zone for the reactions is usually inside the kiln. Therefore, the reagents need to be injected into the gas stream inside the rotating kiln. Once the injection point is fixed, there is little opportunity to control the temperature of the kiln gases. Good dispersion of the reagents in the gas stream is also more difficult to achieve in long wet and long dry kilns. Therefore, it had been thought the effectiveness of SNCR in these systems was reduced.”

### Commercial availability of SNCR

SNCR is commercially available for control of NO<sub>x</sub> emissions from PH/PC cement kilns in the US and has been routinely used to control NO<sub>x</sub> emissions from cement kilns in Europe for several years. However, SNCR technology for a long wet or long dry kiln application is not currently commercially available and would be considered ‘innovative’ technology if it did. Engineers located throughout Lechler’s worldwide facilities worked collaboratively



Figure 3: thick-walled protection tube and spray nozzle lance with barrier air

to demonstrate a commercially-available SNCR injection system with long wet and dry rotating kilns at a cement facility in the US. Figure 2 depicts a long kiln with injection location at one of the US installations.

### SNCR equipment and controls

Onsite storage vessels and a truck-unloading skid are required to receive the delivery of aqueous ammonia to the injection spray location. The ammonia solution is pumped through pipes and delivered into the precalciner or preheater tower through an injection spray lance as depicted in Figure 3. This injection process

requires a pump, pump skid and ammonia-flow control unit. The exact location and number of injection points will differ from one system to the next and is optimised through testing or experience. Figure 4 shows three injection lances at three different injection zones. Measurement equipment is necessary to maintain the appropriate ammonia feed rate. Additional monitoring equipment is required to record the amount of NO<sub>x</sub> and ammonia slip in the gases exiting the SNCR system to adjust the amount of ammonia entering the system. Temperature monitors are also required to make sure that the ammonia is delivered to the correct location.

### Long kiln SNCR system design challenges

The commercial design of an injection system for a rotary long kiln brings several challenges.

#### Kiln rotation

SNCR reaction is highly dependent on the flue gas temperature. The maximum reaction efficiency is at a temperature of around 960°C. In a long kiln this temperature is inside the kiln. This condition requires the ammonia to be injected inside the rotating kiln. To achieve this, the spray lances must be installed on the kiln shell.

However, this poses an additional challenge regarding material selection to prevent wear from the raw mill on the lances at very high temperatures. The lances were designed with thick-walled



Figure 4: inside a rotating kiln with three spray lance injection points at three different zones



Figure 5: rotary coupling and tube bundle support

protection tubes to compensate for wear inside the kiln. Figure 3 shows the lance spraying out of the thick-walled protection tube.

High heat inside the kiln causes multiple concentric tubes within lances to go through differential expansion. To prevent thermal damage to the lances, expansion joints were included to prevent premature lance failure.

The lances were designed to have protection air to prevent the nozzles plugging with dust. Barrier air also prevents bearding formation around the nozzle due to alkali condensation.

Temperature can shift within the kiln when different fuels are used. Before designing the long-kiln SNCR system, a thermal profile study of the kiln was performed to evaluate the shifts in temperature with different fuels. This is important to achieve good reaction efficiencies and reduce the ammonia usage. Addition of static mixers on the lances should also be considered to enhance the reaction efficiency and to meet a lower outlet limit.

### Installation challenges

To design a reliable system, the number of actuated valves installed on the kiln shell for the lances should be kept to a minimum. Due to high heat radiation, valve actuators are not suitable.

Care must be taken in designing the piping for connecting the skid to the lances. The pipes will have to run along the kiln shell underneath the kiln tyres if there are dust scoops on the kiln and

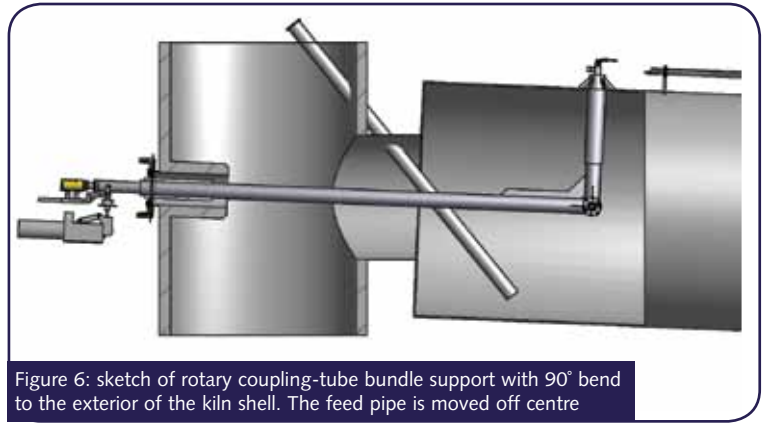


Figure 6: sketch of rotary coupling-tube bundle support with 90° bend to the exterior of the kiln shell. The feed pipe is moved off centre

also possibly inside the kiln shell between the shell and refractory. Also, due to long pipe runs along the shell, pipe insulation may be required to prevent the ammonia from

boiling inside the line. Vaporised ammonia can cause pulsation in flow and can alter the dispersion of ammonia inside the kiln. Very meticulous pressure loss calculation must be performed on the ammonia and compressed air line to prevent one fluid from dead-heading the other. Nozzle design also plays a very important role in maintaining this pressure balance. A poorly-designed nozzle can easily cause flow balance issues within the lance.

The feed lines were connected to a rotary coupling for maintaining the pipe rotations. All utilities (compressed and barrier air, aqueous ammonia, cooling water to control thermal expansion and in certain cases water for gas cooling) were channelled through this rotary coupling.

The design of this coupling must be robust to withstand the heat and high dust that is normally present near the raw meal feed end of the kiln. The rotary coupling is connected to a tube bundle that carries all these utilities inside the kiln (see Figure 5) and after it makes a 90° bend before coming out of the kiln shell. Since a very large surface area of this tube bundle is exposed to hot gases, the bundle is water jacketed and heavily insulated to prevent the ammonia from vaporising within the bundle. Cooling also helps the bundle in maintaining the material strength at higher temperatures. This cooling is achieved by using a heat exchanger.

The tube bundle can easily exceed 700kg. Moreover, this bundle was designed to withstand the abrasion caused by the raw mill feed at each successive kiln rotation and to maintain the horizontal portion of the tube bundle concentric to the kiln shell. This design minimises both stresses on welds and the kiln shell.



Figure 7: pump-metering skid designed by Lechler

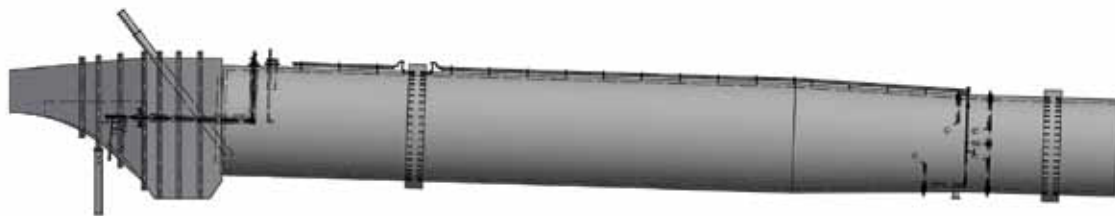


Figure 8: this rotary kiln shows one zone injection with a water lance to cool the kiln gas



Figure 9: Lechler custom-designed support for the rotary coupling tube bundle which allows for movement with the kiln while maintaining support

Outside the kiln, this tube bundle is supported on a constant support device that provides a continuous support during the kiln runout. The design of this support is very critical for a successful installation. Cement kilns typically expand a few inches when heated during production. Due to this expansion, the centre of kiln can move up to 12in side to side and from top to bottom, causing the kiln's centre axis to shift. The constant support responds to these deviations and maintains the support requirement at all times.

In some cases, the feed tube and the water injection lances must be shifted to other positions to provide the tube bundle access to the kiln's centre axis.

The pump and metering injection skids were designed to control the aqueous ammonia, air flowrate and pressure (see Figure 7). All actuated valves that were required to switch ammonia flowrate to different injection banks were installed on the skid and not on the rotating kiln shell.

### Performance & success of long kilns in the US

Lechler commercially installed its first SNCR system in the US in 2009 and since then the company has installed 14 such systems to-date. All had different issues and site constraints that were unique to each plant. Lechler carried out a detailed review of each site and project, and provided the rotary coupling, constant support, pump and control skid, tube bundle, tube bundle support, heat exchangers, water injection lances, connection piping between control skid and lances, lance headers and ammonia injection lances.

Lechler also carried out supervision to contractors and plant operators during installation. All systems have been running efficiently and are meeting all the process performance requirements.

### References

<sup>1</sup> EUROPEAN COMMISSION (2001) Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries

December 2001.

<sup>2</sup> HORTON, J, LINERO, A AND MACGREGOR, F ET AL (2006) 'Use of SNCR to control emissions of oxides of nitrogen from cement plants'. Proceedings of 2006 IEEE Conference.

<sup>3</sup> NEUFFER, B AND LANEY, M (2007), Alternative Control Techniques Document Update – NO<sub>x</sub> Emissions from New Cement Kilns. US Environmental Protection Agency.

<sup>4</sup> KOUKY, W, MERRILL, R, GOSSMAN, D, MILLER, G AND MILLER, G (2006) Assessment of NO<sub>x</sub> emissions reduction strategies for cement kilns – Ellis County. Cement kiln report (final 07.14.2006).

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<sup>6</sup> US ENVIRONMENTAL PROTECTION AGENCY (1994) Controlling nitrogen oxides under the Clean Air Act: a menu of options. Internet: <http://infohouse.p2ric.org/ref/02/01245/3017108.pdf>



Figure 10: Lechler spray lance injection at the kiln